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AFATL-TR-77-19

FABRICATION AND TEST OF VOLUME SCAN TRANSMITTER/RECEIVER MODULE BRASSBOARD, AN INTEGRAL PART OF THE MISSILE ATTITUDE MEASUREMENT SYSTEM

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FEBRUARY 1977

FINAL REPORT: MARCH - DECEMBER 1976

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19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 18 AFATL-TR-77-19	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 FABRICATION AND TEST OF VOLUME SCAN TRANSMITTER/RECEIVER MODULE BRASSBOARD, AN INTEGRAL PART OF THE MISSILE ATTITUDE MEASUREMENT SYSTEM.		5. TYPE OF REPORT & PERIOD COVERED 9 Final Rep[redacted]t, Mar[redacted]-Dec[redacted] [redacted]76,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 K. K. Colson C. T. Thomas		8. CONTRACT OR GRANT NUMBER(s) 15 F08635-76-C-0202 Mw
9. PERFORMING ORGANIZATION NAME AND ADDRESS Texas Instruments Incorporated P.O. Box 6015 Dallas, Texas 75222		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62602F Project No. 16 1921 Task No. 01 Work Unit No. 008
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Armament Laboratory Armament Development and Test Center Eglin Air Force Base, Florida 32542		12. REPORT DATE 11 Feb[redacted] [redacted]977 17 D1
		13. NUMBER OF PAGES 12 40p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government agencies only; this report documents test and evaluation; distribution limitation applied February 1977. Other requests for this document must be referred to the Air Force Armament Laboratory (DLMQ), Eglin Air Force Base, Florida 32542.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC
JUL 18 1977
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18. SUPPLEMENTARY NOTES

Available in DDC.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Missile Attitude Measurement System
Drone Scoring System
Solid-State Laser, Electro-Optics Equipment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A transmitter/receiver module brassboard, a key portion of the overall volume scan Missile Attitude Measurement System (MAMS), designed under Contract F08635-75-C-0087, has been fabricated and tested. With the exception of two recommended circuit changes that are expected to improve the range resolution, the transmitter/receiver module design has been proven by this fabrication and testing program.

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PREFACE

This report was prepared by Texas Instruments Incorporated, P.O. Box 6015, Dallas, Texas 75222, under Contract F08635-76-C-0202, with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida 32542. Mr. Freeland D. Crumly (DLMQ) managed the program for the Air Force Armament Laboratory. This effort was conducted during the period from March to December 1976.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER:

Clifford H. Allen Jr.

CLIFFORD H. ALLEN, JR., Colonel, USAF
Chief, Guided Weapons Division

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SECTION I
INTRODUCTION

This contract is a follow-on to Contract F08635-75-C-0087 which was a design study of a Missile Attitude Measurement System (MAMS). The objective of this latest program was to fabricate a single laser transmitter/receiver (T/R) module and related processing electronics to demonstrate the feasibility of the mechanical, optical, and electrical principles as conceived under the previous study program.

The MAMS, of which the T/R module forms an integral part, provides not only the range and vector to the point of warhead fuzing and the point of closest approach but also provides data for accurately determining the missile attitude relative to the target. This information is important in scoring the overall performance of the missile. A complete and detailed discussion of a design for a MAMS that could be mounted on airborne target drones to score missile firings and that would provide coverage of 90 percent of the space around the drone is contained in the final report of the design study.[1]

Section II of this report contains a brief review of the system concept and circuit design.

Section III contains a summary of the test results obtained during laboratory tests and during the demonstration test of the completed T/R module.

Section IV contains a summary of the contract effort and conclusions drawn from this work.

[1] AFATL-TR-76-40, Design and Analysis Study for Prototype Laser Missile Attitude Measurement System, April 1976.

SECTION II
SYSTEM DESIGN

A. SYSTEM CONCEPT

In a complete MAMS, as described in Reference 1, several modules are included in each sensor package to provide hemispherical coverage of a target drone. Figure 1 illustrates a conceptual view of one such sensor package.

To demonstrate feasibility of the design, one T/R module and its related electronics were fabricated and evaluated. The T/R module sensor unit was divided into two assemblies: a sensor package and the processing electronics. Figures 2 through 4 are photographs of these assemblies. The sensor package contains the T/R module, laser drivers, current source, preamplifiers, multiplexers, and postamplifiers. The processing electronics assembly consists of the peak enhancement circuit, zero crossing circuits, time interval measuring (TIM) circuits, master oscillator, memory, controller, and display. Figure 5 is a block diagram of the complete T/R module brassboard.

The T/R module consists of the optics, laser diodes, detector array, and Freon cooling chamber. The three laser diodes are sequentially pulsed and, in conjunction with their respective optical elements, produce a laser light beam with angular dimensions of 5 milliradians by 10 degrees for each diode or a total beam dimension of 5 milliradians by 30 degrees. Freon 22® is evaporated within the cooling chamber to lower the operating temperature of the laser diode to $-20°C$.

The 12-element silicon diode detector array, combined with a single aspheric lens, subtends a total field of view of 30 degrees by 33 milliradians. Each detector element subtends 33 by 33 milliradians with an 11-milliradian spacing between the detector elements.

B. CIRCUIT DESIGN

The electronic design for the transmitter/receiver module brassboard closely follows the design developed during the design study (Reference 1). The sensor electronics consists of three 4-channel preamplifiers, four 3-channel-to-1-channel multiplexer circuits, two dual-channel post-amplifiers, a laser firing circuit, and a current source. The sensor electronics is separated from the processing electronics and interconnected with two cables to simulate the normal operational configuration.

The processing electronics consists of four identical channels comprising a peak enhancement circuit, zero crossing circuit, and a time interval measurement circuit.

In the following subsections, problems encountered during the T/R module brassboard development and changes made to the planned design are described. For a better understanding of this material, Reference 1 should be studied.

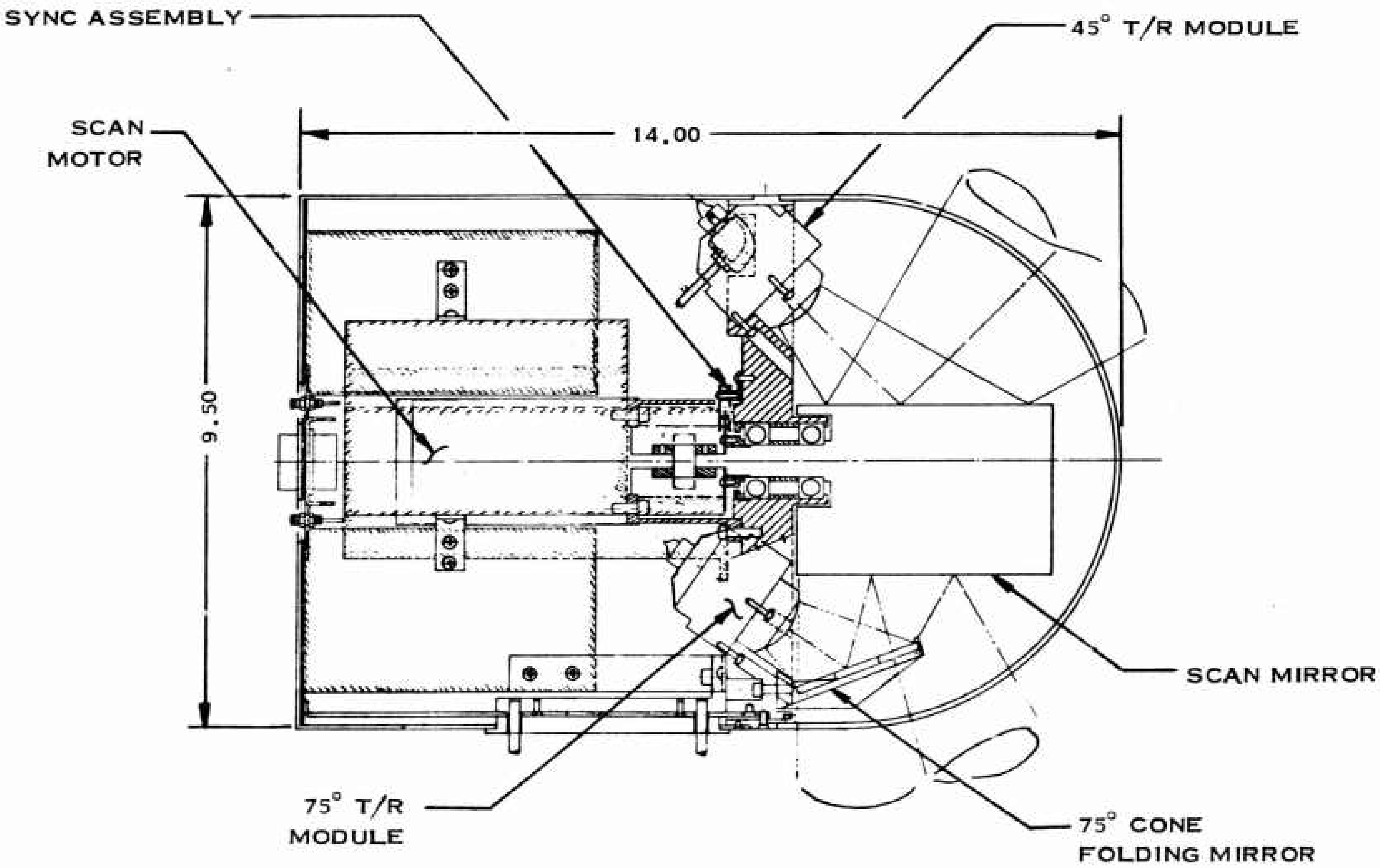

Figure 1. Hemisphere Sensor Bulkhead Scan Assembly

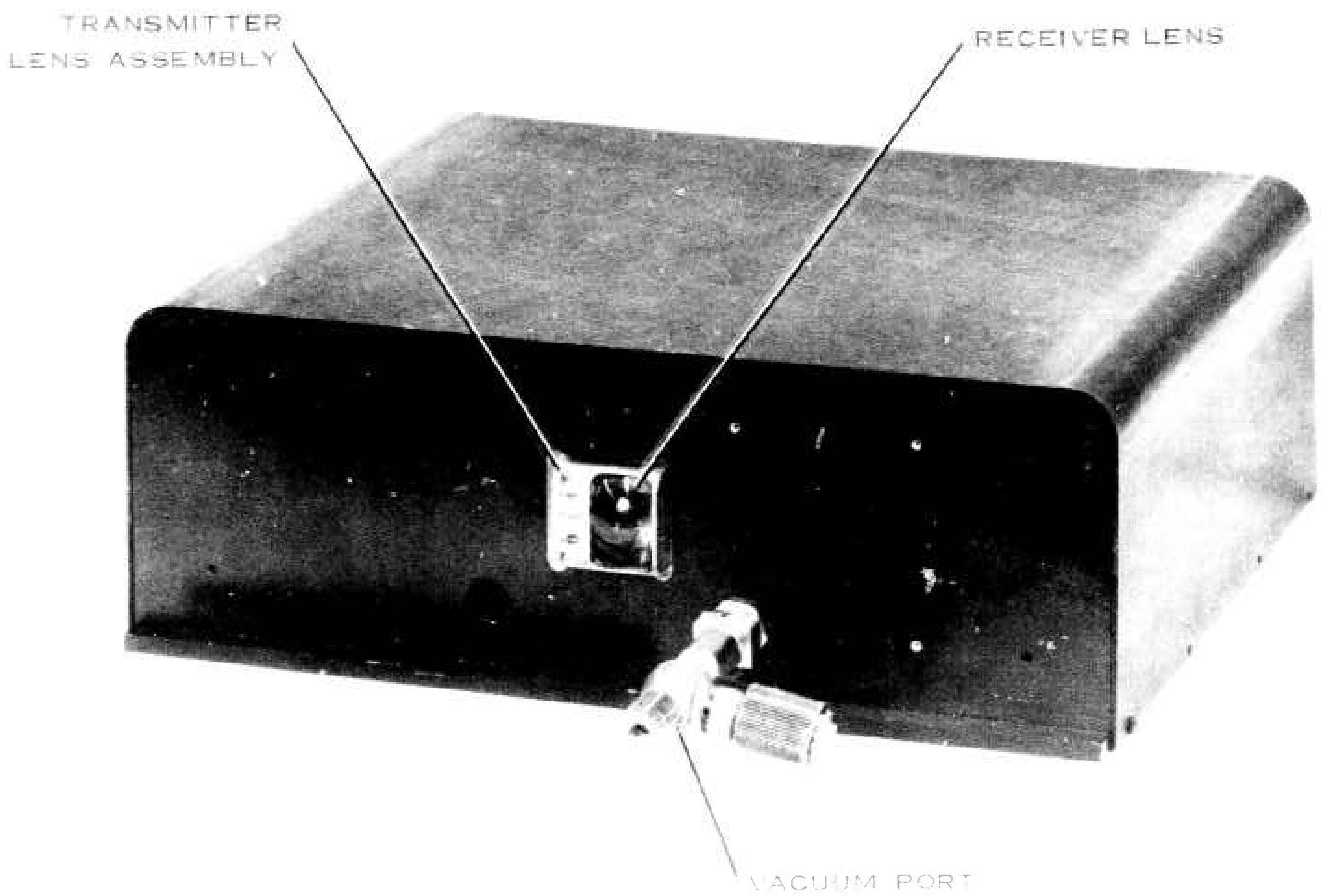

Figure 2. External View of Sensor Package

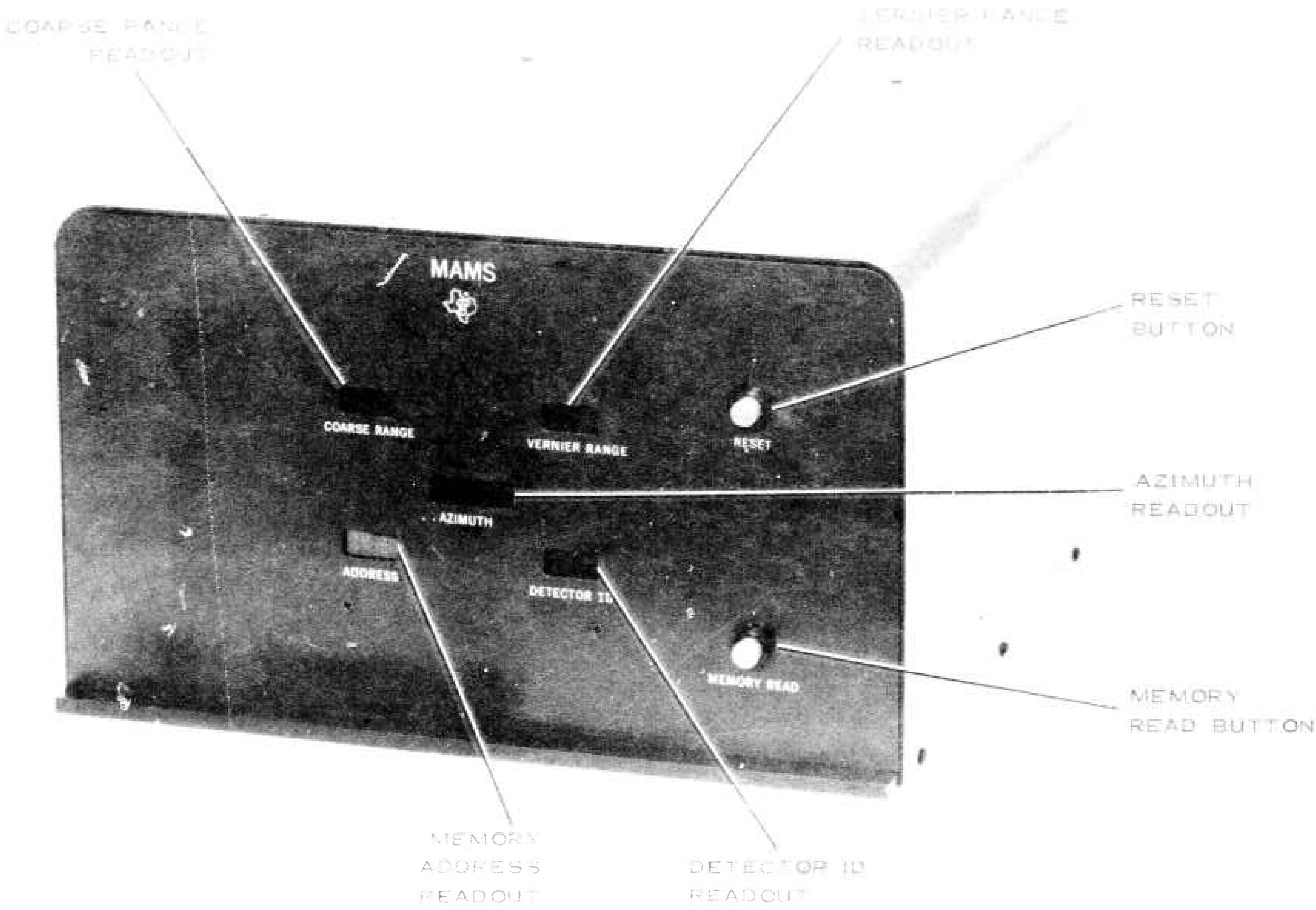

Figure 3. External View of Electronics Package

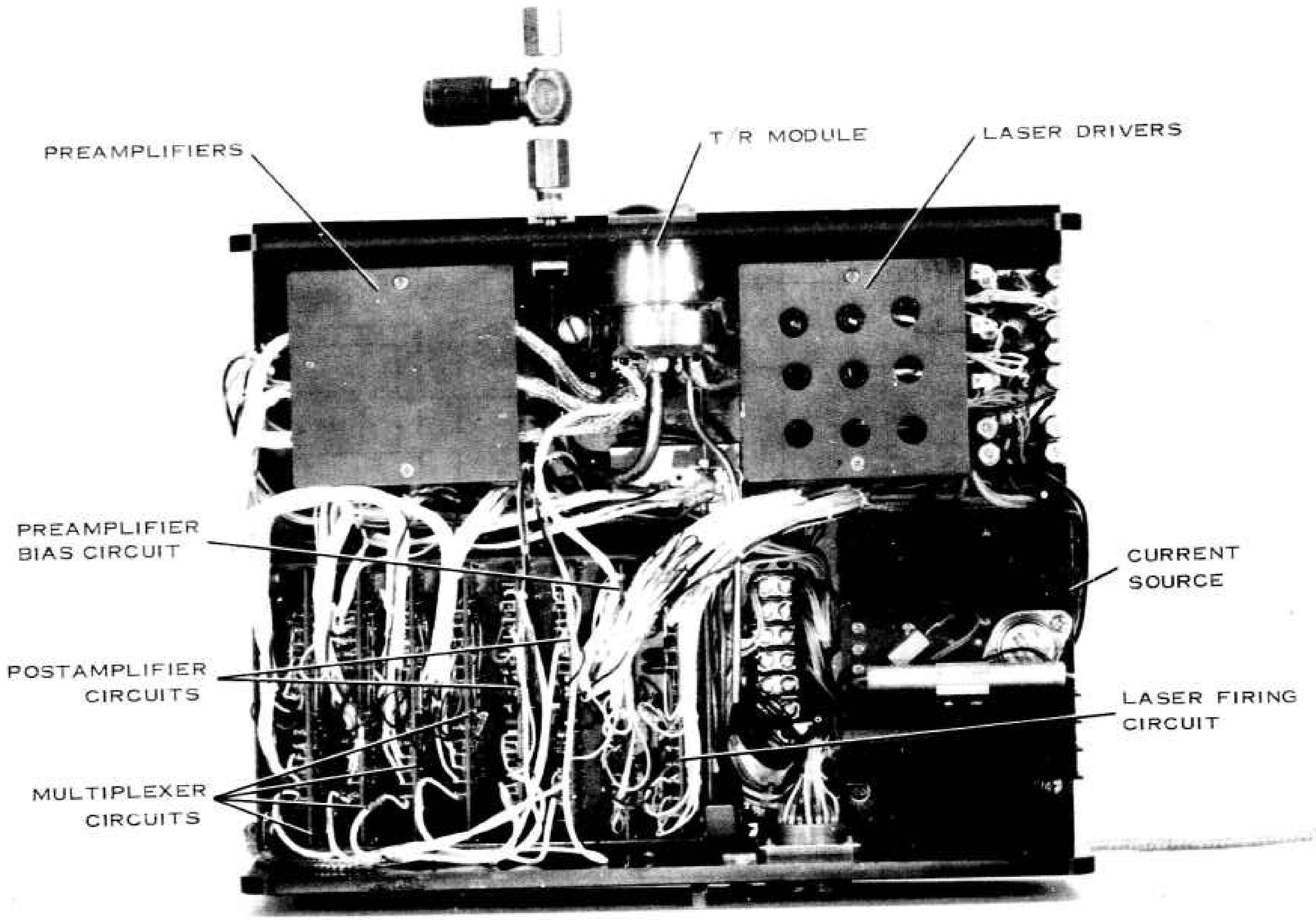

Figure 4. Internal View of Sensor Package

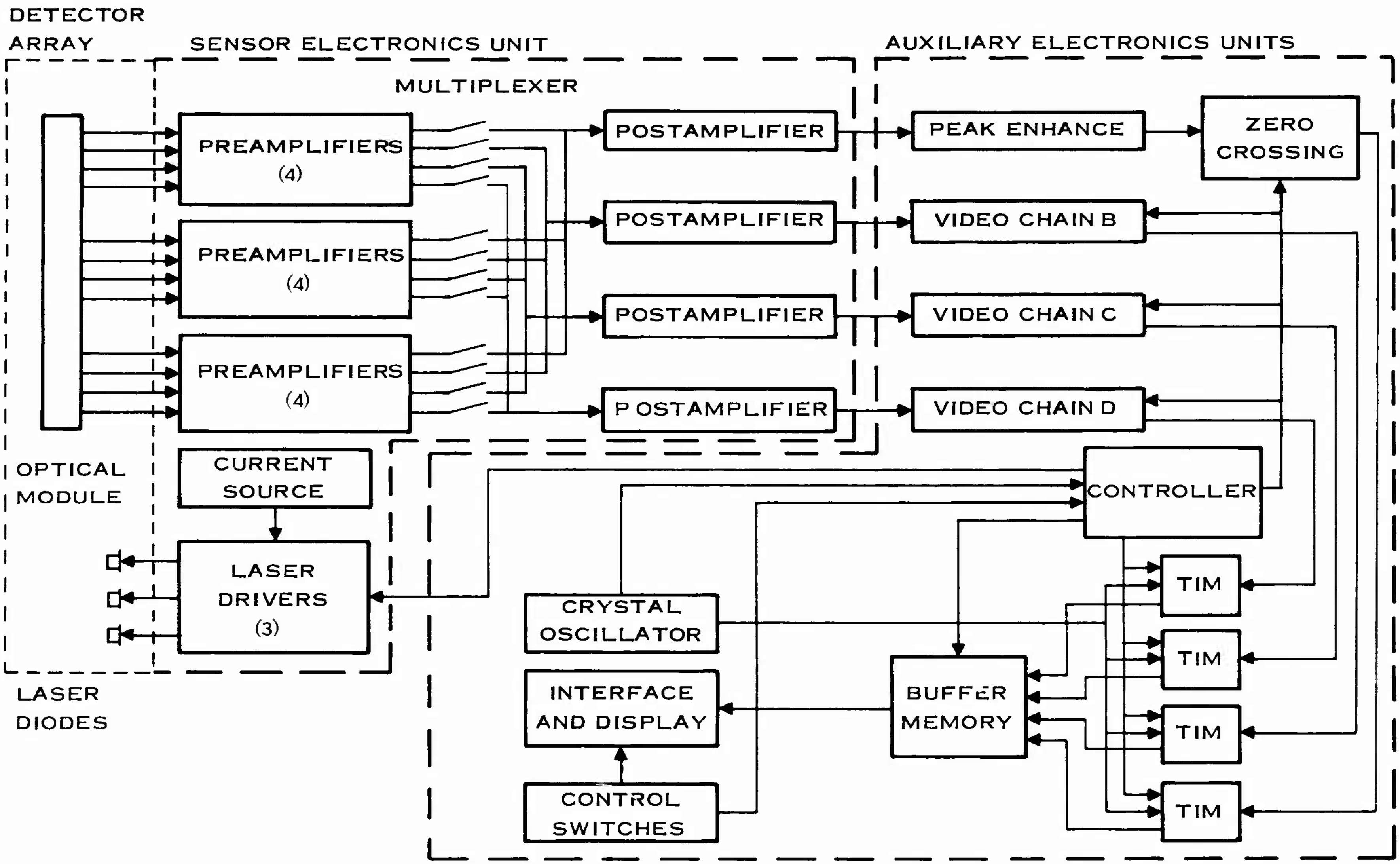

Figure 5. Block Diagram of Transmitter/Receiver Module Brassboard

C. LASER DRIVER

The laser driver circuit described in Reference 1 was redesigned to use six 2N2219 transistors operating in parallel. Preliminary testing of the 2N3501 transistors indicated that two devices would avalanche simultaneously when connected in parallel, but the 2N3501 transistors acquired for the brassboard system would not avalanche together. Both transistors would start to avalanche, but one transistor would fall out of avalanche until the first transistor discharged its capacitor, at which time the second transistor would restart its avalanche process. The net effect of this interaction was a double current pulse, with the peaks separated by approximately 20 nanoseconds, and a reduced peak current.

During the redesign of the laser driver, the reactance of the laser diode in the stud-mounted configuration was determined to be approximately 14 nanohenrys. This inductance and the associated inductance of the current path from the driver circuit tend to limit the minimum rise time and pulsewidth to 5 nanoseconds and 20 nanoseconds, respectively. The length of the current path is a critical design parameter, as may be seen from the results in Section III.

A ½-inch length of ¼-inch braid reduced the radiant intensity of the transmitter beam by a factor of 1.5. In a final production unit, the use of hybrid circuit drivers mounted adjacent to the diode will eliminate the long current path and produce laser diode outputs with relatively even intensity.

D. MULTIPLEXER CIRCUIT

The multiplexer circuit, described in Figure 44 of Reference 1, contains multiplexing field-effect transistors and a variable gain control and delay line for each video channel. It was determined during the design study that the amplitude measuring capability was not needed. Since there was no longer a need for amplitude equalization for each video channel, variable gain controls were removed.

As the effective time resolution of the system is approximately 0.2 nanosecond, a variable delay line was placed in each video line to eliminate variations in signal path length. The variable delay lines purchased for this system fail to meet the specified rise time, resulting in a stretched pulse from the multiplexer circuit. This results in a shallower zero crossing signal and greater uncertainty in the range measurement. Also, as the delay lines are terminated in their characteristic impedance at both the input and output, the power of the signal is reduced by 50 percent. Delay lines having a better pulse response can improve the performance of the system. It now appears that a better solution would be to eliminate the delay lines and to make a total delay correction for each channel in the digital processing section, which would be a part of a complete MAMS. A stored binary number representing the total electronics delay of each detector channel will be subtracted from the output of a time interval measurement for that channel. This change will not only improve the performance but will also eliminate the need for the delay correction at each TIM circuit.

E. COOLDOWN DETECTION

To prevent damage to the laser diodes from operation at temperatures above −20°C, a cooldown circuit detects the temperature of the laser diode coldfinger and inhibits the laser trigger until cooldown is achieved. The present configuration of the cooldown detector consists of a 1N4148 diode biased at 1 milliampere. The voltage drop across the diode junction changes at an approximate rate of 2 millivolts per degree Celsius change in temperature. Measurement of the diode junction voltage provides an indication of the temperature of the coldfinger. With the present configuration, the radiated magnetic field from the high-current line to the laser diode induces a voltage spike in the cooldown circuit line that is rectified by the temperature sensing diode giving an erroneous temperature reading. This problem may be remedied in future designs by using a thermistor in place of the diode.

F. ANALOG VIDEO PROCESSING

Two problems were encountered in the analog video processing. One problem was the EMI pickup in the low-voltage supply and interconnecting video lines. Another problem was an apparent reduction in the signal-to-noise ratio by the logarithmic amplifier.

G. EMI PICKUP

For purposes of testing of the T/R module brassboard, discrete wiring was used to provide power to each board in the video chain, and terminated coaxial lines were used for video transmission between boards. This approach uses considerable power because of the low termination impedance required for coaxial lines. The long runs for the low-voltage supply lines increase the susceptibility to noise pickup. These problems could be corrected through the use of a mother board for interconnections and power distribution. Experience with other equipment designs indicates that, by using a mother board, power line runs are shorter and are not as susceptible to noise pickup as are hardwired systems.

H. LOGARITHMIC AMPLIFIER

The logarithmic amplifier increases the system dynamic range with a response, as shown in Figure 46 of Reference 1. One problem noted with the present processing is that the threshold for a minimum signal is limited by the noise occurring in the receiver channels immediately following the transmitted pulse. Since the return signal would be very high if not limited by the logarithmic amplifier during this period, performance could be improved by eliminating the logarithmic amplifier and by making the threshold a decreasing function of time after the transmitted pulse. The required dynamic range could be retained by adding another peak enhancement circuit. The threshold level would be adjusted so that the minimum expected signal would exceed the threshold by at least 200 millivolts, at which time the amplifier would function as the peak enhancement circuit described by Figure 47 of Reference 1.

I. TIME INTERVAL MEASURING CIRCUIT

The performance of the TIM circuit (Figure 49 of Reference 1) was improved by using a diode AND gate formed by two Schottky diodes (1N5711) in the vernier oscillator coincidence line and in the crystal clock coincidence line. The two outputs are then NANDed together to form the leading-edge coincidence pulse. The resolution of the coincidence circuit was measured to be 0.05 nanosecond when using a pulse generator as an input.

The proposed 54S124 gatable oscillator was found to be off frequency for the first three to four counts. This introduced an erroneous count for ranges requiring only a few vernier counts. A 54S00 NAND gate with an L-C timing network was found to provide a rapid-starting oscillator without the off-frequency startup problem.

The coincidence pulse used to stop the vernier oscillator would not reliably stop the coarse counter. The trailing edge of the stop gate to the vernier oscillator was used to stop the coarse counter, and the problem was corrected. The input latch on the TIM circuit would not reliably hold the set position. Introduction of a slowdown capacitor in the lockout line allows the gate to be reliably set upon receipt of a start pulse.

In future designs, all counts will be reset to zero at the start of a transmit signal. Electronic delay correction will be accomplished by the computer as described previously.

J. MEMORY

Because of the high data rate of the T/R module brassboard, the memory devices from the previous brassboard were replaced with bipolar RAMs. The AUGAT wire-wrap board from the previous system was used. A problem encountered with the memory was the failure of the system to reliably reset and store correct data. Only one channel of the 4-channel input worked reliably. This problem was believed to be associated with intermittent integrated-circuit connections on the wire-wrap board.

K. TRANSMITTER OPTICS DESIGN

The transmitter optics were first built according to the design shown in Table II of Reference 1. Initial tests showed that this design did not provide sufficient divergence to provide a 10-degree beam. The design was rechecked, and the radius, R_1, of the cylindrical lens was changed from 0.3333 inch to 0.1666 inch. The lenses were rebuilt to this design, and the proper beam spread was obtained.

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SECTION III

PERFORMANCE TESTS

The test procedure and test data sheets describing the T/R module brassboard demonstration tests are included as appendixes to this report. A brief discussion of the results of the individual tests follows.

A. TRANSMITTER FIELD OF VIEW

The transmitter field of view (FOV) was measured to be 30.5 degrees in elevation and average 5.7 milliradians in azimuth. These results compare favorably with the design values of 30 degrees elevation and 10 milliradians azimuth.

B. TRANSMITTER BEAM POWER DENSITY

The transmitter beam power density, uniformity, and pulse period were measured during this test. The minimum measured radiant intensity of the transmitter beam was 5,945 watts/steradian, which compared favorably to the 5,714-watt/steradian value computed during the design study. Reduction of the length of the current path by use of hybrid laser drivers mounted adjacent to the laser diodes will increase the radiant intensity and make the beam power density for each of the diodes more nearly equal since the measured variation in radiant intensity was caused primarily by the variations in the length of the current path between the laser drivers and the laser diodes.

The period between pulses was measured to be 19.0 microseconds, indicating that the pulse repetition frequency was 52.6 kHz.

C. RECEIVER FIELD OF VIEW AND NOISE EQUIVALENT INTENSITY

The angular limits in azimuth of the receiver field of view were measured for each detector channel during this test using a test transmitter.

The noise equivalent intensity (NEI) for each channel was calculated by using a measured signal-to-noise ratio for each detector channel and the calibrated beam density for the test transmitter.

The average beamwidth for the 12 receiver channels was 35.4 milliradians, which compares favorably with the 33-milliradian design value.

The measured noise values for each channel were greater than the basic amplifier noise because of pickup from the multiplexer switching circuits. The noise was found to be much lower when the multiplexers were turned off. This additional noise does not affect system operation since it occurs during the multiplexer switching time, but it does cause the calculated NEI values to be higher than predicted.

A better way of measuring system sensitivity should be found for future tests. One possible method could be to determine the threshold intensity level by placing calibrated neutral-density filters in front of the test transmitter and observing the lowest intensity at which the receiver will reliably provide range indications.

D. RANGE ACCURACY AND RESOLUTION

This test was performed by setting the target at a measured range, reading the range with the T/R module brassboard, and then moving the target closer in decreasing increments. The measurements indicated a bias error of about 1 foot and a resolution capability of about 1 foot when the readings from each range position were averaged. Part of the error was caused by a one-count error in the coarse count on some readings, which was apparently the result of the memory board problem discussed previously. If all the coarse-count errors were corrected, the bias error would be about 2 feet, but the resolution capability becomes about 0.5 foot.

Using the 27-MHz signal bandwidth of the T/R module brassboard, the predicted one-sigma range resolution is 0.6 foot, which agrees with the measured resolution of 0.5 foot.

Increasing the bandwidth of the electronics by removal of the variable delay lines should improve the range resolution.

The bias error in the range readings will be corrected by the computer method of correcting for the electronic delay.

E. MISSILE ATTITUDE MEASURING CAPABILITY

For the tangential attitude measurements, the target was set about 20 feet away in a plane normal to the T/R module beam and at an angle of 30 degrees with the vertical. The target was then stepped across the beam in 2½-inch increments, the distance that would be scanned in one pulse period at that range. For two of the positions, the detector number stored and displayed had dropped the leading 1 of the two-digit number because of the memory problem discussed in Section II. When the data were corrected for this problem, the plot of the return signals gave an estimated angle of 26 degrees compared to the 30 degrees at which the target was set. A mathematical handling of the data to provide a straight-line fit by the least-squares method gave a value of 30.9 degrees.

The radial measurement was not attempted because of the range resolution problem discussed in Section II.

The T/R module brassboard was set up with a contractor-owned scanner unit, and it was determined that the beam could be scanned, but no data were taken in this mode of operation.

F. FREON CONSUMPTION

To determine the Freon consumption of the T/R module, a running log was maintained and the consumption rate was determined to be approximately 1 pound per hour. The measured operating temperature of the laser diodes was approximately $-40°C$ and liquid coolant was being exhausted from the T/R module.

The Freon flow rate was set higher than the original design value to prevent orifice clogging, which would occur on the brassboard after several hours of operation.

An analysis of the actual heat load indicates that one module could maintain a −20°C temperature at the diodes with a Freon flow rate of 0.35 pound per hour. The vacuum seal design for the module proved to be very effective. After the initial evacuation, no further evacuation was required during the 1-month testing period.

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SECTION IV

SUMMARY AND RECOMMENDATIONS

A T/R module with its associated electronics was fabricated, assembled, and tested. The performance estimates of the design study (Reference 1) were confirmed with the exception of the expected range resolution. Removal of the variable delay lines and incorporation of a threshold which varies as a function of time after the transmitter pulse should provide the required range resolution.

As the logical next step in the development cycle, it is recommended the range resolution be verified after making the above changes to the T/R module brassboard. Based on the results from the T/R module brassboard development, the advanced development model program could then proceed with very low technical risk.

APPENDIX A

DEMONSTRATION TEST PROCEDURE*

PART I
INDIVIDUAL TEST FOR
T/R MODULE BRASSBOARD
CONTRACT NO. F08635-76-C-0202

1. TABLE OF TESTS.

1.1 Scope, general.

This procedure outlines the tests required and the means for implementing these tests to demonstrate that the T/R module brassboard meets the requirements of Contract No. F08635-76-C-0202.

1.2 List of tests to be performed.

Test	Procedure Paragraph
Transmitter field of view	3.2.1
Transmitter beam power density, uniformity, and pulse period	3.2.2
Receiver field of view and noise equivalent intensity	3.2.3
Range accuracy and range resolution	3.2.4
Demonstration of missile attitude measuring capability	3.2.5

2. LIST OF TEST EQUIPMENT

2.1 Test Data Sheet (Texas Instruments Drawing SK-GH-31) shall be completed as a part of this test.

2.2 Verify that test equipment is currently certified per Texas Instruments Standard Procedure No. 18-12. (Stamp)

2.3 Commercial test equipment–The following commercially available test equipment (or equivalent) is required to complete the tests required for this procedure.

Oscilloscope–Tektronix, Model 454 or equivalent.

RMS voltmeter–Hewlett-Packard, Model 3400A or equivalent.

2.4 Special test equipment–The following special test equipment is required to complete the tests of this procedure.

Test transmitter, Part No. SK-GH-28 (calibration sticker not required).

*Test data sheet SK-GH-31 to be filled out as part of this procedure.

2.5 Support equipment—The following support equipment will be used but will not require calibration and certification.

Test receiver, Part No. SK-GH-29

RS 300 scanner

Optical rail and tripod

6 inch by 6 foot reflective target with stand

Laboratory power supplies, ±15, +5, −120 Vdc, +28 Vdc

Battery supply, +150 volts

Metascope (IR viewer)

Commercial measuring tape, 10 feet or longer.

2.6 Power requirements.

115 volts, single phase, 60 Hz.

3. TEST PROCEDURES.

3.1 Preparation.

3.1.1 Operational preparation—The T/R module brassboard shall be prepared for operation by interconnecting units and power supplies as shown in Figure A-1.

3.1.2 Inspection—Before each test, visually inspect the T/R module brassboard to ensure that the set is in good condition with no damage to items or parts. (Check)

3.2 Functional tests.

3.2.1 Transmitter field of view.

3.2.1.1 Preparation—The T/R module brassboard shall be prepared for operation according to paragraph 3.1.1 of this procedure.

3.2.1.2 Test steps.

WARNING

Laser light is present during this test.

3.2.1.2.1 Ensure Freon cooling lines are properly connected and open cooling valve.

3.2.1.2.2 Turn system on by turning on ±15-Vdc, +5-Vdc, and −120-Vdc power supplies.

3.2.1.2.3 Position the T/R module chassis on a table surface at least 40 inches high so that the transmitted laser beam is imaged on a large sheet of paper mounted on the wall approximately 12 feet from the front face of the T/R module.

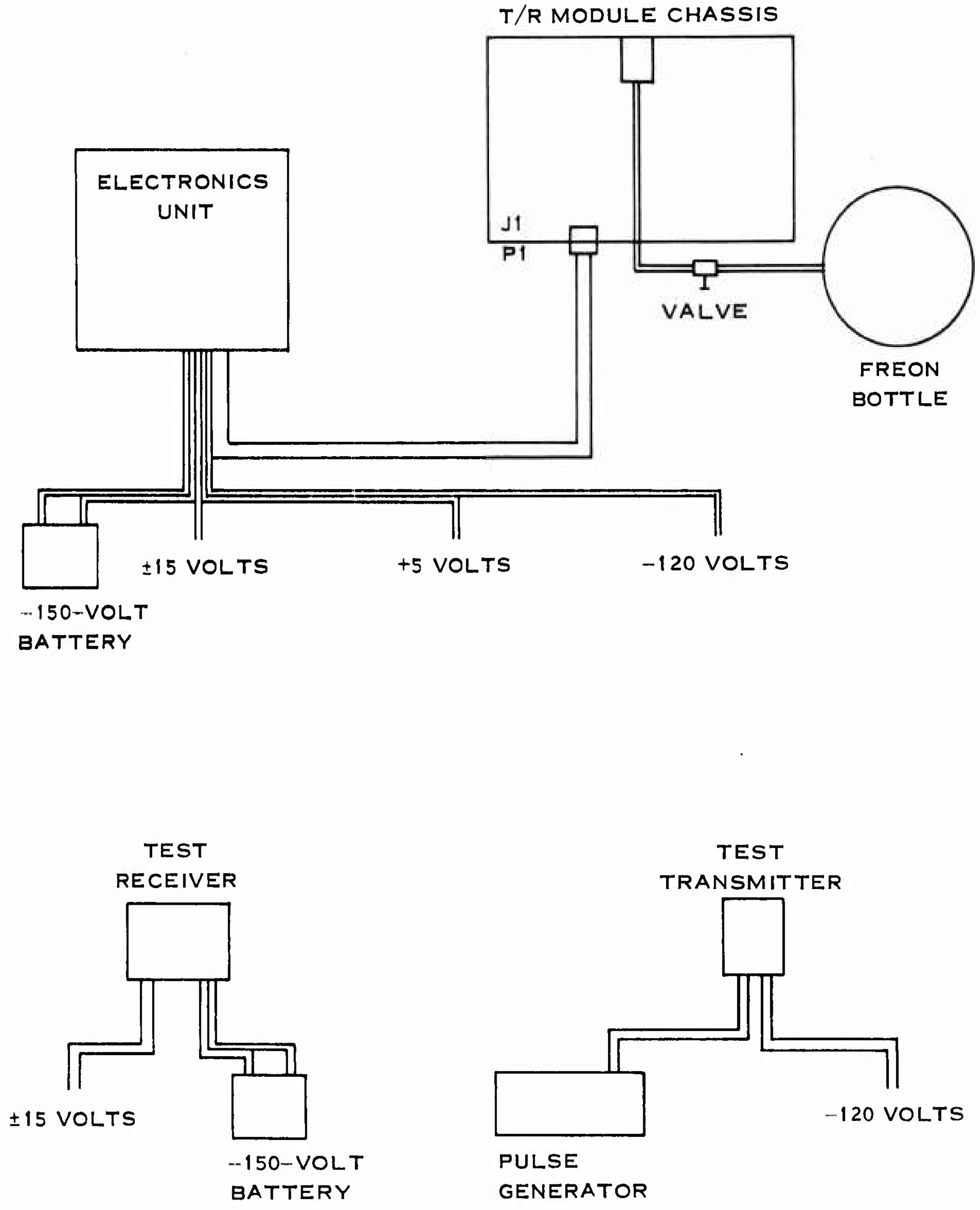

Figure A-1. Interconnections for Transmitter/Receiver Module Test

3.2.1.2.4 Using the Metascope IR viewer, determine the location of the top and bottom edges of the transmitter beam and mark location on the paper. Also, mark the left and right edges of the beam at five locations along the height—at approximately 6 inches and 18 inches from both top and bottom and at the approximate center.

3.2.1.2.5 Turn off the power supplies and close the Freon valve.

3.2.1.2.6 Measure the distance in inches from the front face of the module to the location of the center of the beam on the paper. Record value as d_1 on data sheet. (Record)

3.2.1.2.7 Measure the distance in inches from the front face of the module to the center of the other four width marks on the paper. Measure beginning with the top marks and record distances in order from top to bottom as d_2, d_3, d_4, and d_5. (Record)

3.2.1.2.8 Measure the beam widths on the paper in inches, first at the center and then at the other four locations in order from top to bottom, and record on data sheet as W_1, W_2, W_3, W_4, and W_5. (Record)

3.2.1.2.9 Measure the height of the beam in inches and record on data sheet as h. (Record)

3.2.1.2.10 Calculate transmitter beam width in milliradians at five locations from the following equations:

$$\Delta\phi_{T_1} = W_1/d_1 \times 1000$$

$$\Delta\phi_{T_2} = W_2/d_2 \times 1000$$

$$\Delta\phi_{T_3} = W_3/d_3 \times 1000$$

$$\Delta\phi_{T_4} = W_4/d_4 \times 1000$$

$$\Delta\phi_{T_5} = W_5/d_5 \times 1000$$

Record results on data sheet. (Record)

3.2.1.2.11 Calculate transmitter beam height in degrees from the following equation:

$$\Delta\phi_T = 2 \arctan \frac{h}{2d_1}$$

Record results on data sheet. (Record)

3.2.2 Transmitter Beam Power Density, Uniformity, and Pulse Period

3.2.2.1 The T/R module brassboard shall be prepared for operation according to paragraph 3.1.1 of this procedure.

3.2.2.2 Test steps.

WARNING

Laser light is present during this test.

3.2.2.2.1 Set up the test receiver and the test transmitter so that the test transmitter will illuminate the test receiver and the distance between the devices will be about equal to the d_1 measurement from the previous test. Connect the test receiver output to an oscilloscope. Connect the required power supplies to both devices and turn on the power supplies. Using the oscilloscope, observe the peak voltage of the pulses at the test receiver output. Adjust the position of the optical axes of the test transmitter and test receiver as required to obtain the maximum output. Record the peak voltage on the test data sheet as V_T. (Record)

3.2.2.2.2 Move the test receiver to the location of the center of the transmitter beam as determined from the previous test. Turn on Freon and power supplies for the T/R module and observe the peak voltage of the pulse at the test receiver output. Adjust the alignment of the optical axis of the test receiver until maximum output is obtained.

3.2.2.2.3 Record the peak voltage of the pulses on the test data sheet as V_1. (Record)

3.2.2.2.4 Move the test receiver to the approximate positions of the other four beamwidth measurements as described in paragraph 3.2.1.2.4 and repeat step 3.2.2.2.1 at each position. Record the peak voltages on the test data sheet as V_2, V_3, V_4, and V_5. (Record)

3.2.2.2.5 Using the calibrated radiant intensity, J_T, in peak watts/steradian for the test transmitter, calculate the radiant intensity of the T/R module in peak watts/steradian at the five locations as follows:

$$J_1 = \frac{V_1}{V_T} J_T \left(\frac{d_1}{d_6}\right)^2$$

$$J_2 = \frac{V_2}{V_T} J_T \left(\frac{d_2}{d_6}\right)^2$$

$$J_3 = \frac{V_3}{V_T} J_T \left(\frac{d_3}{d_6}\right)^2$$

$$J_4 = \frac{V_4}{V_T} J_T \left(\frac{d_4}{d_6}\right)^2$$

$$J_5 = \frac{V_5}{V_T} J_T \left(\frac{d_5}{d_6}\right)^2$$

where J_T = 8.645 peak watts/steradian. Record the calculated values on the test data sheet. (Record)

3.2.2.2.6 With the test receiver operating in the final location of step 3.2.2.2.2, set oscilloscope to measure the period between transmitter pulses. Record the period on the test data sheet. (Record)

3.2.2.2.7 Turn off the power supplies and the Freon valve.

3.2.3 *Receiver Field of View and Noise Equivalent Intensity*

3.2.3.1 The T/R module brassboard shall be prepared for operation according to paragraph 3.1.1 of this procedure.

3.2.3.2 Test steps.

WARNING

Laser light is present during this test.

3.2.3.2.1 Set up tripod and optical rail with the optical rail horizontal and approximately in line and normal to the direction of the T/R module transmitter beam at a distance approximately 6 feet from the front face of the T/R module.

3.2.3.2.2 Attach the test transmitter to the optical rail so that it points toward the T/R module. Attach the rms voltmeter and oscilloscope input to the preamplifier output for detector A of the T/R module.

3.2.3.2.3 Turn on the ±15-Vdc and +5-Vdc power supplies for the T/R module. Turn on the pulse generator and the −120-Vdc power supply for the test transmitter.

3.2.3.2.4 Move the tripod up or down as required to provide a signal at the channel A output. Move the test transmitter along the optical rail until a peak signal is obtained and then readjust tripod up and down for a peak signal in that direction. Read the peak signal on the oscilloscope in volts. Record as S on the data sheet. (Record)

3.2.3.2.5 Read the test transmitter clamp position on the optical rail. Record as B_C in centimeters on data sheet. (Record)

3.2.3.2.6 Move the test transmitter to the left (with reference to line of sight toward the face of the T/R module) along the optical rail until the signal drops to 50 percent of the peak value. Read the test transmitter clamp position. Record as B_L in centimeters on data sheet. (Record)

3.2.3.2.7 Repeat step 3.2.3.2.6 but move the test transmitter to the right on the optical rail. Record as B_R in centimeters on the data sheet. (Record)

3.2.3.2.8 Turn off test transmitter and read rms noise voltage at the channel A preamplifier output. Record as N on data sheet. (Record)

3.2.3.2.9 Measure the distance from the test transmitter to the T/R module receiver lens. Record as d on data sheet. (Record)

3.2.3.2.10 Repeat steps 3.2.3.2.2 through 3.2.3.2.9 substituting channels B through L, in order, for the channel A instructions. (Record)

3.2.3.2.11 Calculate NEI values from the following equation:

$$NEI = J_T \frac{1}{d^2} \frac{N}{S}$$

where

J_T = test transmitter radiant intensity
= 8.645 watts/steradian

d = distance from test transmitter to T/R module receiver in centimeters

S = signal measurement in volts

N = noise measurement in volts

NEI = expressed in watts/cm².

3.2.3.2.12 Calculate receiver beam widths from the following equation.

$$\Delta\phi_R = \frac{B_R - B_L}{d} \times 1000$$

where B_R, B_L, and d are in centimeters and $\Delta\phi_R$ is in milliradians.

3.2.4 Range accuracy and resolution.

3.2.4.1 Preparation–The T/R module brassboard shall be prepared for operation according to paragraph 3.1.1 of this procedure.

3.2.4.2 Test steps.

3.2.4.2.1 Set up test target on test stand with long axis horizontal and normal to the direction of the T/R module optical axis at a distance of about 20 feet from the T/R module.

3.2.4.2.2 Turn T/R module on by first turning on Freon valve and then turning on +5-, ±15-, and −120-volt power supplies. Press RESET button on the control panel and hold for about 1 second.

3.2.4.2.3 Press MEMORY READ button on the control panel and record the panel indicator readings under the appropriate column on the data sheet. (Record)

3.2.4.2.4 Repeat step 3.2.4.2.3 until data have been read from all 16 addresses in the memory. (Record)

3.2.4.2.5 Turn off power supplies and then turn off Freon valve.

3.2.4.2.6 Calculate the range for each set of data from the following equation:

Range in feet = 6 X coarse reading + 0.1 X vernier reading

Take an average of the calculated ranges. (Record)

3.2.4.2.7 Measure the range from the target surface to the front surface of the T/R module. (Record)

3.2.4.2.8 Decrease the range by 1.0 foot and record the new measured range. (Record)

3.2.4.2.9 Repeat steps 3.2.4.2.2 through 3.2.4.2.6. (Record)

3.2.4.2.10 Decrease the range by 0.5 foot and record the new measured range. (Record)

3.2.4.2.11 Repeat steps 3.2.4.2.2 through 3.2.4.2.6. (Record)

3.2.4.2.12 Decrease the range by 0.2 foot and record the new measured range. (Record)

3.2.4.2.13 Repeat steps 3.2.4.2.2 through 3.2.4.2.6. (Record)

3.2.5 Demonstration of missile attitude measuring capability.

3.2.5.1 Preparation. The T/R module brassboard shall be prepared for operation according to paragraph 3.1.1 of this procedure.

3.2.5.2 Test steps.

WARNING

Laser light is present during this test.

3.2.5.2.1 Set up target with reflective surface facing T/R module at a 20-foot range and with the long axis making a 30-degree angle with the vertical in a plane normal to the T/R module axis.

3.2.5.2.2 Turn on Freon valve and turn on +5-, ±15-, and −120-volt power supplies.

3.2.5.2.3 Using the Metascope IR viewer as a guide, move the target mount left or right as required until the top end of the target is illuminated by the transmitter beam.

3.2.5.2.4 Press RESET button on control panel and then press MEMORY READ. Record the display data for first three addresses. (Record)

3.2.5.2.5 Move the target mount left or right as required to stay on the target, a distance of 2½ inches (equivalent to distance traveled during one transmitter pulse period when scanning target at 20-foot range). Repeat step 3.2.5.2.4. (Record)

3.2.5.2.6 Repeat step 3.2.5.2.5 twelve times. (Record)

3.2.5.2.7 Based on the detector center-to-center angular subtense of 0.0436 radian, use the recorded data to plot out the received signal pattern. Determine a computed tangential angle from the plot and compare to the actual angle. (Record)

3.2.5.2.8 Set the target to make a 30-degree angle to the vertical in a plane parallel to the line of sight of the T/R module. Using the Metascope IR viewer, align target with transmitter beam.

3.2.5.2.9 Press RESET button and hold for 1 second and then press MEMORY READ button 16 times to read out and record all data stored in memory. (Record)

3.2.5.2.10 Using a polar coordinate graph, plot recorded data from 3.2.5.2.9 and predict radial attitude. Compare to the actual angle. (Record)

3.2.5.2.11 Turn off Freon valve and power supplies.

3.2.5.2.12 Set up T/R module in relation to RS 300 scanner unit as shown in Figure A-2. Supply 28-volt power to the scanner motor and connect oscilloscope to shaft index pulse indicator. Adjust 28-volt supply until mirror shaft speed is 2800 RPM. This corresponds to an optical scan rate of 628.3 radians/second.

3.2.5.2.13 Repeat tests described in steps 3.2.5.2.1 through 3.2.5.2.11 but do not move the target as described in steps 3.2.5.2.3 through 3.2.5.2.6 since this will be accomplished by the scanner. There may be some false data stored in the memory register since the scan mirror reflects back into the receiver for a small portion of the scan. Using the stored true target data, plot out the return patterns as described in 3.2.5.2.7 and 3.2.5.2.10. For the tangential attitude test, the stored data should be arranged in probable order of return and associated with azimuth scan steps calculated from the scan rate and the pulse period as measured in step 3.2.2.2.6.

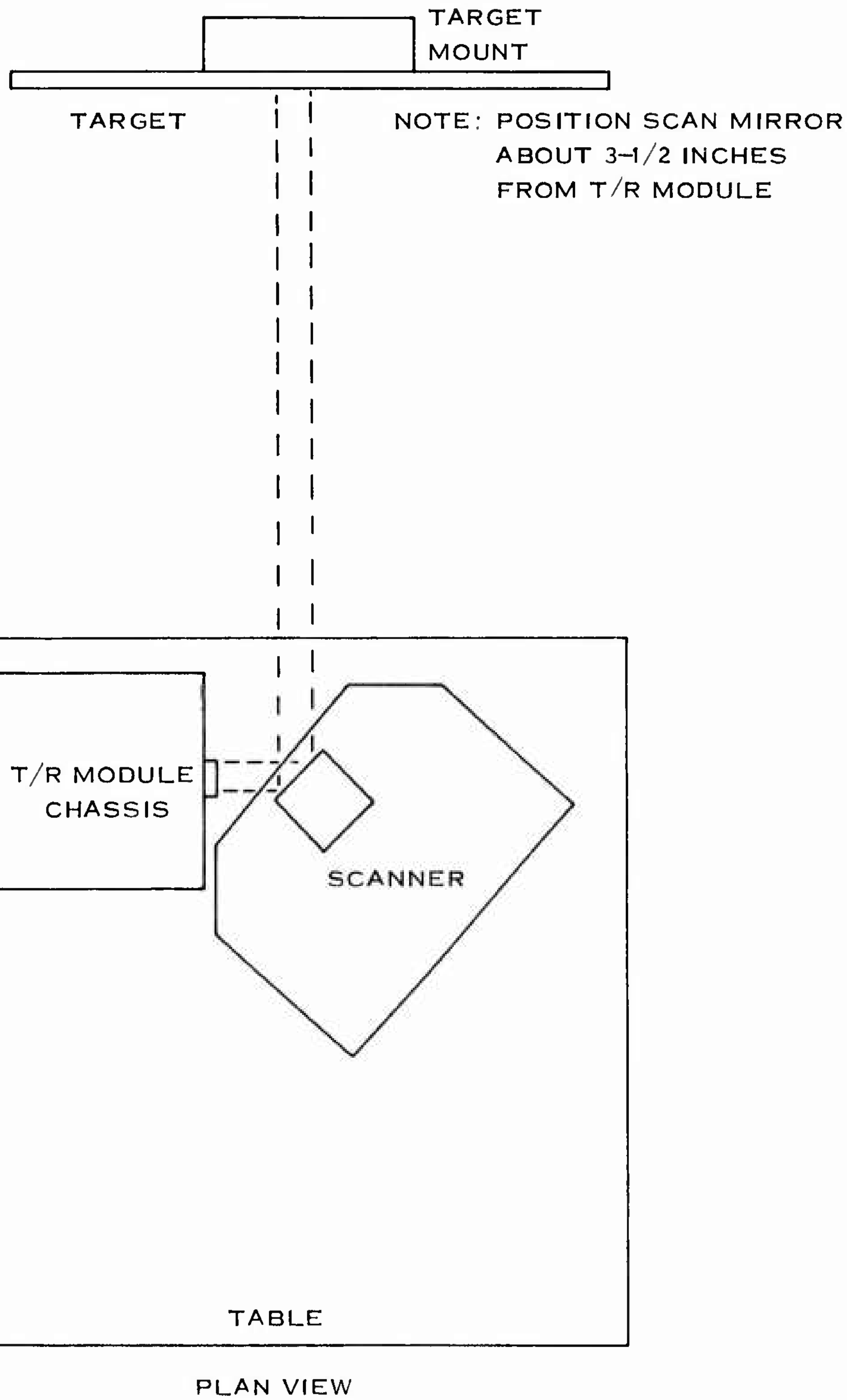

Figure A-2. Test Setup for Scanner Demonstration Test

APPENDIX B

DEMONSTRATION TEST DATA SHEET*

PART I

INDIVIDUAL TEST FOR
T/R MODULE BRASSBOARD
CONTRACT NO. F08635-76-C-0202

All paragraph numbers refer to demonstration test procedure.

2.2	Verify that test equipment is currently certified.	______	(Stamp)
3.1.2	Visual inspection		(Check)
3.2.1.2.6	Distance, d_1	132	(Inches)
3.2.1.2.7	Distance, d_2	137	(Inches)
	Distance, d_3	134.5	(Inches)
	Distance, d_4	133.75	(Inches)
	Distance, d_5	135.25	(Inches)
3.2.1.2.8	Beam width, W_1	0.839	(Inches)
	Beam width, W_2	0.774	(Inches)
	Beam width, W_3	0.835	(Inches)
	Beam width, W_4	0.747	(Inches)
	Beam width, W_5	0.650	(Inches)
3.2.1.2.9	Beam height, h	72	(Inches)
3.2.1.2.10	Calculated transmitter beam width, $\Delta\phi_{T_1}$	6.36	(Milliradians)
	Beam width, $\Delta\phi_{T_2}$	5.65	(Milliradians)
	Beam width, $\Delta\phi_{T_3}$	6.21	(Milliradians)
	Beam width, $\Delta\phi_{T_4}$	5.61	(Milliradians)
	Beam width, $\Delta\phi_{T_5}$	4.8	(Milliradians)
3.2.1.2.11	Calculated transmitter beam height, $\Delta\phi_T$	30.5	(Degrees)
3.2.2.2.1	Test transmitter peak voltage, V_T d_6 = 13.875 inches	0.160	(Volts)
3.2.2.2.3	T/R module peak voltage, V_1 d_1 = 9 feet 2¼ inches	2.60	(Volts)
3.2.2.2.4	T/R module peak voltage, V_2 d_2 = 9 feet 6 inches	2.0	(Volts)
	T/R module peak voltage, V_3 d_3 = 9 feet 3 5/8 inches	1.70	(Volts)
	T/R module peak voltage, V_4 d_4 = 8 feet 10¼ inches	2.70	(Volts)
	T/R module peak voltage, V_5 d_5 = 9 feet 1½ inches	2.40	(Volts)

3.2.2.2.5	Radiant intensity of T/R module, J_1	8870 (watts/steradian)
	Radiant intensity of T/R module, J_2	7295 (watts/steradian)
	Radiant intensity of T/R module, J_3	5945 (watts/steradian)
	Radiant intensity of T/R module, J_4	8555 (watts/steradian)
	Radiant intensity of T/R module, J_5	8076 (watts/steradian)
3.2.2.2.6	Period between transmitter pulses	19.0 (Record)

3.2.3.2.4 to
3.2.3.2.12

Channel	S (volts)	N (volts)	B_C (cm)	B_L (cm)	B_R (cm)	d (cm)	NEI (watts/cm^2)	$\Delta\phi_R$ (mrad)
A	0.140	0.0012	31.0	30.0	33.0	70	1.5×10^{-5}	42.8
B	1.0	0.0013	21.5	17.5	24.0	161	4.3×10^{-7}	40.4
C	1.2	0.00125	20.5	17.0	23	167	3.23×10^{-7}	35.9
D	1.1	0.00135	20.0	17.0	22.5	168	3.5×10^{-7}	32.7
E	1.0	0.0012	20.5	16.5	22.5	168	3.67×10^{-7}	35.7
F	0.9	0.00135	20.0	16.5	22.5	170	4.14×10^{-7}	35.3
G	0.8	0.0012	20.0	15.5	21.5	171	4.43×10^{-7}	35.1
H	0.9	0.00125	21.0	18.5	24.25	164.1	4.46×10^{-7}	35.0
I	1.1	0.0029	21.5	17.5	23.5	164.1	8.3×10^{-7}	36.6
J	1.2	0.0026	22.5	18.5	24.25	164	6.9×10^{-8}	35.0
K	0.7	0.0027	22	19.0	23.5	166	1.21×10^{-6}	27.1
L	0.6	0.0027	21	19.5	25.0	167	1.39×10^{-6}	32.9

3.2.4.2.3 to
3.2.4.2.4

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)
1.	13	03	54	23.4
2.	13	02	35	15.5
3.	13	03	52	23.2
4.	13	03	48	22.8
5.	13	03	42	22.2
6.	13	03	58	23.8
7.	13	03	59	23.9
8.	13	03	38	21.8
9.	13	04	56	29.6
10.	13	03	54	23.4
11.	13	03	50	23.0
12.	13	03	39	21.9
13.	13	02	39	15.9
14.	13	03	43	22.3

3.2.4.2.4 (Continued)

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)	Data With Coarse Range Error Deleted
15.	13	02	37	15.7	
16.	13	02	45	16.5	

3.2.4.2.6	Total	344.9	251.7
	Average	21.56	22.8
3.2.4.2.7	Measured range	20.75	
3.2.4.2.8	New measured range	19.75	

3.2.4.2.9

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)	Data With Coarse Range Error Deleted
1.	13	02	26	14.6	
2.	13	03	40	22.0	
3.	13	03	35	21.5	
4.	13	03	36	21.6	
5.	13	03	36	21.6	
6.	13	03	46	22.6	
7.	13	03	31	21.1	
8.	13	02	30	15.0	
9.	13	02	38	15.8	
10.	13	03	38	21.8	
11.	13	03	36	21.6	
12.	13	02	31	15.1	
13.	13	02	33	15.3	
14.	13	03	36	21.6	
15.	13	02	41	16.1	
16.	13	03	36	21.6	
Total				308.9	347.2
Average				19.3	21.7

3.2.4.2.10 New measured range 19.25

3.2.4.2.11

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)	Assuming Coarse Range = 3
1.	13	02	33	15.3	21.3
2.	13	02	39	15.9	21.9
3.	13	02	33	15.3	21.3
4.	13	03	32	21.2	21.2
5.	13	03	35	21.5	21.5
6.	13	02	31	15.1	21.1
7.	13	02	23	14.3	20.3
8.	13	03	31	21.1	21.1
9.	13	03	31	21.1	21.1

3.2.4.2.11 (Continued)

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)	Assuming Coarse Range = 3
10.	13	02	33	17.3	21.3
11.	13	03	32	21.2	21.2
12.	13	02	34	15.4	20.4
13.	13	02	34	15.4	21.4
14.	13	03	28	20.8	20.8
15.	13	03	28	20.8	20.8
16.	13	03	27	20.7	20.7
Total				313.6	337.4
Average				19.6	21.1

3.2.4.2.12 New measured range 19.05

3.2.4.2.13

Address	Detector ID	Coarse Reading	Vernier Reading	Range (feet)	Using Coarse = 3
1.	13	02	31	15.1	21.1
2.	13	03	31	21.1	21.1
3.	13	03	36	21.6	21.6
4.	13	03	34	21.4	21.4
5.	13	02	29	14.9	20.9
6.	13	02	30	15.0	21.0
7.	13	03	30	21.0	21.0
8.	13	02	30	15.0	21.0
9.	13	03	27	20.7	20.7
10.	13	03	28	20.8	20.8
11.	13	02	30	17.0	21.0
12.	13	03	35	21.5	21.5
13.	13	03	30	21.0	21.0
14.	13	02	27	14.7	20.7
15.	13	02	30	15.0	21.0
16.	13	03	34	21.4	21.4
Total				298.2	337.2
Average				18.6	21.075

3.2.5.2.4 Position 1

Address	Detector ID	Coarse Reading	Vernier Reading	Range
1.	01	45	62	
2.	02	02	41	
3.	01	39	6	
	02	02	37	
	02	02	38	

3.2.5.2.5 Position 2

Address	Detector ID	Coarse Reading	Vernier Reading	Range
1.				
2.				
3.				

3.2.5.2.6 Position 3

1.	00	11	35
2.	01	99	52
3.	00	10	38
	00	10	38
	00	10	38
	01	4	51

Position 4

1.	00	08	34
2.	01	39	06
3.	00	10	38
	01	39	06
	00	01	27

Position 5

1.	00	10	38
2.	00	10	38
3.	00	92	10
	00	10	38

Position 6

1.	00	02	38
2.	13	02	26
3.	00	02	38
	13	03	32
	00	02	38

Position 7

1.	13	2	30
2.	13	2	33
3.	13	3	27
	13	3	23
	13	2	27

Position 8

1.	13	03	35
2.	13	02	33
3.	10	08	38
	13	02	34

Address	Detector ID	Coarse Reading	Vernier Reading	Range
Position 9				
1.	12	03	24	
2.	13	03	35	
3.	12	03	24	
	13	03	35	
Position 10				
1.	12	02	22	
2.	12	06	18	
3.	12	02	21	
	12	02	21	
Position 11				
1.	12	03	31	
2.	11	39	06	
3.	12	03	31	
	10	00	26	
	12	03	31	
Position 12				
1.	11	05	45	
2.	11	93	46	
3.	11	02	51	
	11	89	52	
Position 13				
1.				
2.				
3.				
Position 14				
1.				
2.				
3.				

3.2.5.2.7 Computed tangential angle 26 (Degrees)

Actual tangential angle 30 (Degrees)

3.2.5.2.9

Address	Detector ID	Coarse Reading	Vernier Reading	Range
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				

3.2.5.2.10 Predicted radial attitude

Actual angle

3.2.5.2.13

Address	Detector ID	AZ	Coarse Reading	Vernier Reading	Range
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9					
10.					
11.					
12.					
13.					
14.					
15.					
16.					

3.2.5.2.13 Computed tangential angle

Actual angle

3.2.5.2.13

Address	Detector ID	Coarse Reading	Vernier Reading	Range
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				

3.2.5.2.13 Predicted radial attitude

Actual angle

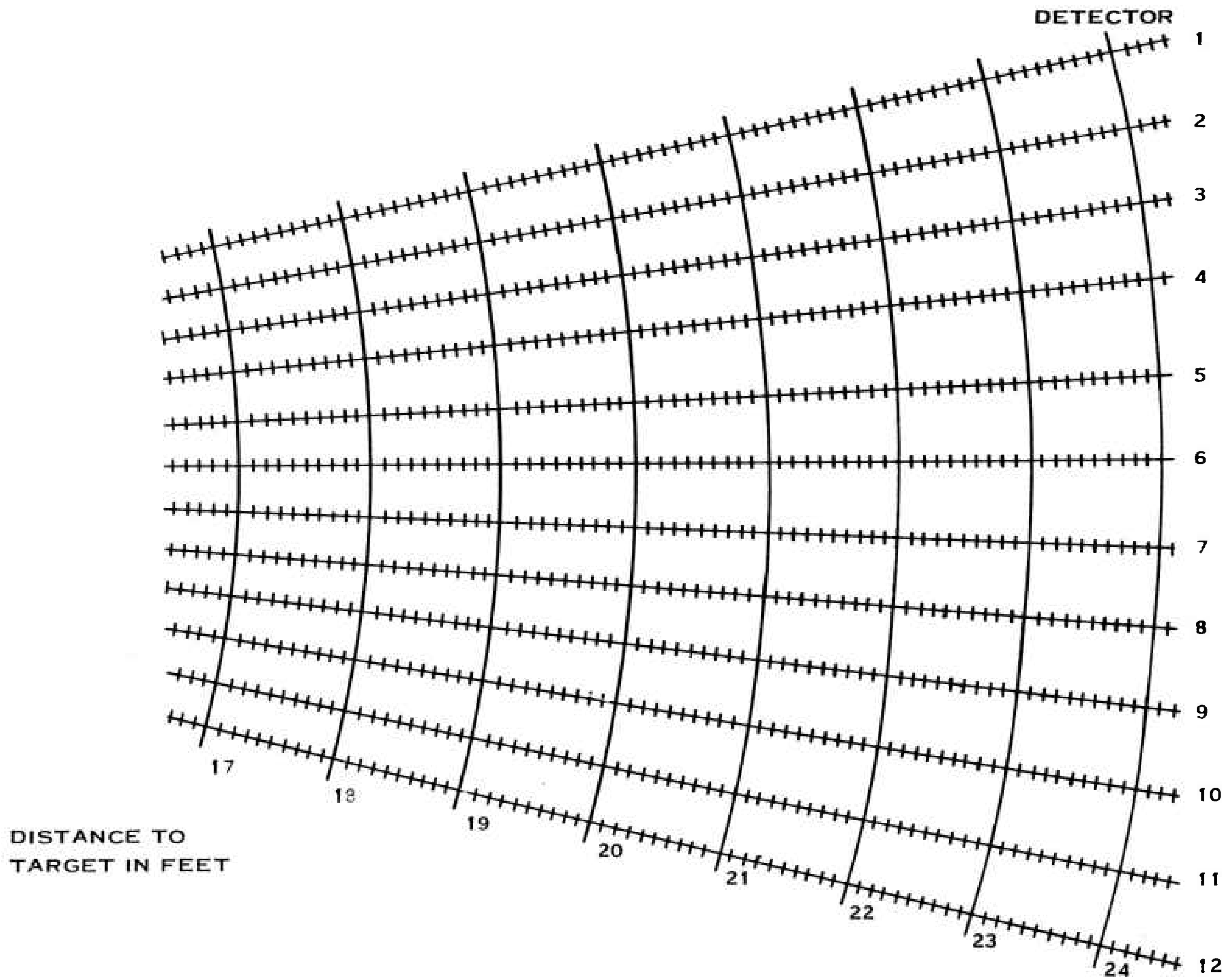

Figure B-1. Target Position

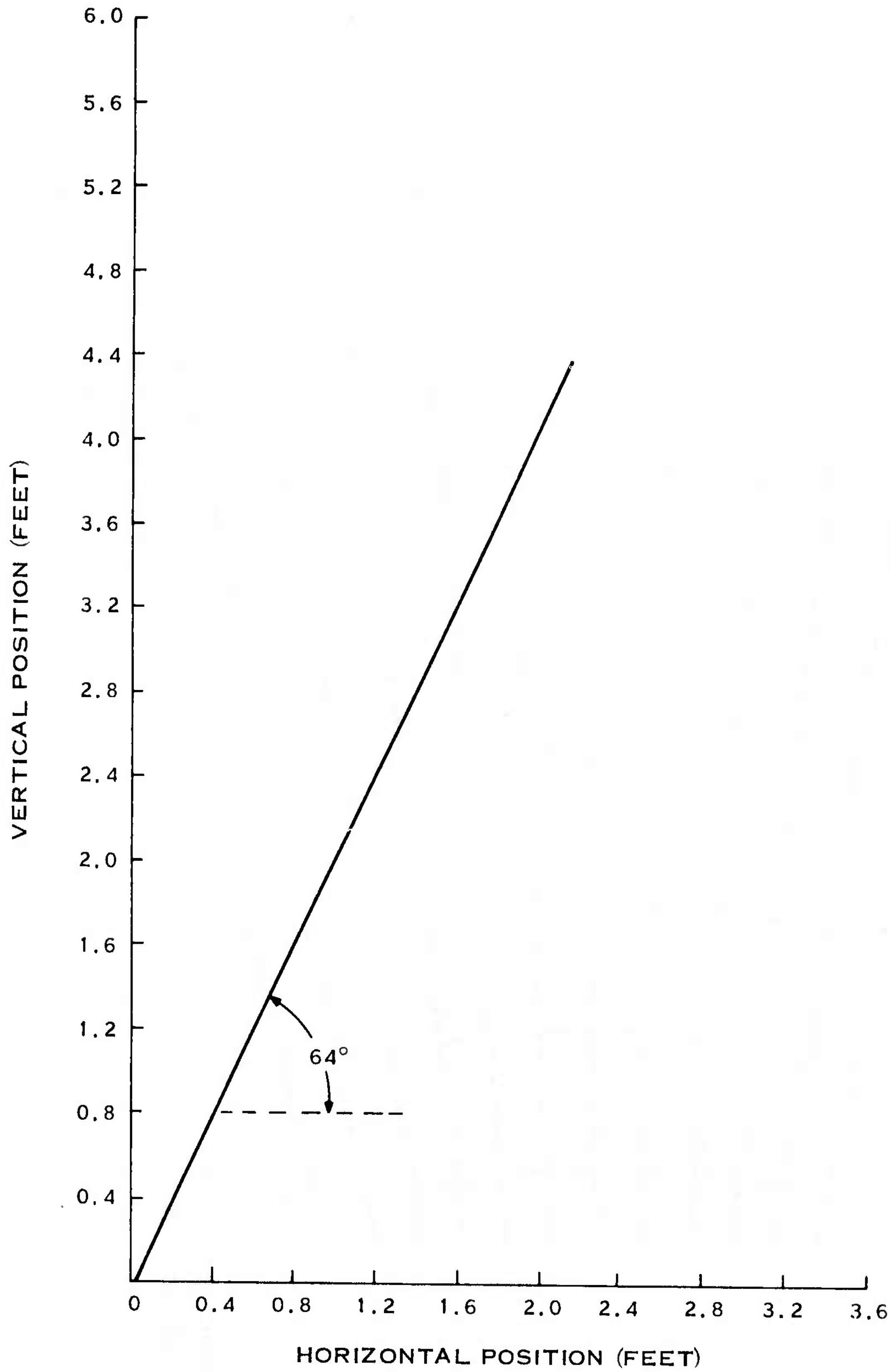

Figure B-2. Target Position

REFERENCES

1. AFATL-TR-76-40, *Design and Analysis Study for Prototype Laser Missile Attitude Measurement System*, April 1976.

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AFSC/SDWM	1
TAC/DRA	2
TAC/XPSY	1
AFAL/AA	1
AFAL/TEM	1
AFAL/RWM	1
AFAL/RW	3
ASD/YHEV	1
ASD/XRG	2
ASD/YFEI	1
ASD/ENO	1
ASD/ENYW	1
ASD/ENASA	1
ASD/YPEX	1
ASD/RWS	1
ASD/RWR	2
ASD/ENFEA	1
ASD/SD (TECH DIR)	1
ASD/SD7	2
ASD/SD5EI	1
ASD/SD4T	2
AFFDL/FE	1
AFFDL/FGL	1
AFFLD/FX	1
AFFDL/FY	1
AFML/MX	1
AFML/LL	1
AFML/MB	1
AFML/LP	1
AFLC/MMWM	1
Ogden ALC/MMWM	2
6585 TG/GDP	1
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Nav Air Systems Comd/AIR-5323	1
Nav Air Systems Comd/AIR-5324	1
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AFATL/DLMA	1
AFATL/DLMI	5
AFATL/DLY	2
AFATL/DLYA	1
AFATL/DLYW	1
AFATL/DLJ	1
AFATL/DLJF	1
AFATL/DLJC	1
AFATL/DLJA	1
AFATL/DLJM	1
AFATL/DLOSL	2
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ASD/SDM	1
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TAWC/TEFA	1
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